Psychophysiological Changes During EMDR and Treatment Outcome

Martin Sack
Technical University Munich, Department of Psychosomatic Medicine and Psychotherapy

Arne Hofmann
University of Cologne, Department of Psychosomatic Medicine

Leah Wizelman
Technical University Munich, Department of Psychosomatic Medicine and Psychotherapy

Wolfgang Lempa
Hannover Medical School, Department of Psychosomatic Medicine and Psychotherapy

This study was designed to investigate the question of whether psychophysiological changes during EMDR sessions are related to subjective and objective reduction of PTSD symptoms. During-session changes in autonomic tone in relation to session-to-session changes of subjective stress, trauma-related symptoms, and psychophysiological reactions during a traumatic reminder were investigated in 10 patients suffering from single-trauma PTSD. Treatment duration followed each patient's individual needs and ranged between 1 and 4 sessions, resulting in a total of 24 EMDR treatment sessions from which psychophysiological data were completely recorded. Treatment with EMDR was followed by a significant reduction of trauma-related symptoms, elimination of the PTSD diagnosis in 8 of the 10 participants, as well as by significantly reduced psychophysiological reactivity to an individualized trauma script. Psychophysiological dearousal in sessions correlated significantly with decrease in script-related reactions in heart rate and parasympathetic tone, and with changes in subjective disturbance. Our results indicate that information processing during EMDR is followed by during-session decrease in psychophysiological activity, reduced subjective disturbance and reduced stress reactivity to traumatic memory.

Keywords: EMDR; psychophysiological assessment; working mechanism; treatment outcome

Eye movement desensitization and reprocessing (EMDR) is an information processing–based treatment technique aiming to integrate maladaptive traumatic memories into functional explicit memory networks. The adaptive information processing model (Shapiro & Maxfield, 2002) predicts that effective trauma therapy will not only resolve trauma-related symptoms but also result in reduced psychophysiological reactivity toward traumatic reminders. This consequence opens the possibility of complementing a questionnaire-based assessment of therapy outcome with more objective measures of physiologically based symptom reduction.

An overview of published research on EMDR reveals four studies reporting treatment-related reductions of cardiovascular activity in response to script-driven imagery (Carlson, Chemtob, Rusnak, Hedlund, & Muraoka, 1998; Renfrey & Spates, 1994; Rogers et al., 1999; Sack, Lempa, & Lamprecht, 2007). Other studies found evidence for a pre- to posttreatment decrease of heart rate and electromyographic activity (Aubert-Khalfa, Roques, & Blin, 2008; Boudewyns, Stwertka, Hyer, Albrecht, & Sperr, 1993; Forbes, Creamer, & Rycroft, 1994; Wilson, Silver, Covi, & Foster, 1996). Together, these findings indicate that EMDR treatment is followed

 DOI: 10.1891/1933-3196.2.4.239

by reduced cardiovascular reactivity to traumatic reminders as well as by reduced basal psychophysiological activity. Although these findings are compelling and support the adaptive information processing model of EMDR, there is still a lack of empirical data about the relationship of during-session changes of psychophysiological activity to therapy outcome in patients treated for posttraumatic stress disorder (PTSD).

Empirical findings from exposure-based behavior therapy in patients with phobic and obsessive compulsive disorders indicate a correlation between during-session dearousal of psychophysiological activity with symptom improvement (Foa & Kozak, 1986). Astonishingly, only sparse research exists on psychophysiological concomitants during treatment sessions in patients suffering from PTSD. In a single case study, Nishith and associates (2002) described a correlation between during-session activation of heart rate (HR) with treatment outcome during prolonged exposure therapy. Wilson and associates (1996) reported significant decreased HR and skin conductance reactions as well as significant increase of fingertip temperature in the course of EMDR treatment sessions. The authors claim a relation between these during-session changes of psychophysiological activity and changes in subjective disturbance (SUD). Unfortunately, no standardized questionnaires or the more objective assessment of psychophysiological reactivity to traumatic reminders were used as outcome criteria in this study. Two newer studies investigating psychophysiological changes of eye movements during EMDR in a naturalistic treatment design also report on significant during-session decreases of psychophysiological activity; however, in these studies, the relation of these changes to treatment outcome was not assessed (Elofsson, von Scheele, Theorell, & Sondergaard, 2008; Sack, Lempa, Steinmetz, Lamprecht, & Hofmann, 2008).

Thus, the current study was designed to investigate the question of whether psychophysiological changes during EMDR sessions are related to subjective and objective reduction of PTSD symptoms. During-session monitoring of psychophysiological variables was complemented with the assessment of psychophysiological reactivity to an individualized trauma script at the beginning of every treatment session. To control for possible effects of repetitive measurement, questionnaire data and trauma script reactivity were assessed twice before treatment started. The presented data were sampled independently from our other published studies on the psychophysiology of EMDR (Sack et al., 2007, 2008).

Method

Participants

Participants were 10 patients (8 women, 2 men) of White ethnic background who requested treatment for trauma-related psychological problems at a specialized trauma clinic. All patients suffered from traumatization by a single incident and fulfilled diagnostic criteria for PTSD as assessed by the German version of the PTSD module of the Structured Clinical Interview for DSM-IV (Wittchen, Zaudig, & Fydrich, 1997). Mean current age was 34 years (range 19 to 48 years).

Following a detailed clinical interview, the employment of EMDR was proposed. After receiving information about the study, all participants gave their written consent. The ethics committee of Hannover Medical School and Technical University Munich approved the study protocol. EMDR treatment strictly followed the protocol suggested by Shapiro (1995) and included all eight phases described in her book. Two authors of this article (MS and WL)—both trained and having more than 10 years of clinical experience administering EMDR—carried out the treatment. The duration of therapy followed each patient's individual needs and ranged from 1 to 4 sessions, resulting in a total of 24 sessions. Pre- and posttreatment assessment and combined assessment and treatment sessions were scheduled with a time interval of one week. Prior to every session, trauma-related symptoms were assessed with the Impact of Event Scale (IES).

Psychophysiological Assessment

Electrocardiogram (ECG) was recorded via the Ambulatory Monitoring System (AMS; Vrije Universiteit, Department of Psychophysiology, Amsterdam, Netherlands), with six disposable Ag/AgCL electrodes (Cleartrace, Conmed Corp., New York) placed on the thorax (De Geus, Willemsen, Klaver, & van Doornen, 1995). Reliability and validity of the VU-AMS device have been reported elsewhere as adequate (Willemsen, De Geus, Klaver, van Doornen, & Carroll, 1996). Indices of parasympathetic drive were obtained by analysis of ECG signals. A root mean square of successive differences of adjacent interbeat intervals (RMSSD) reflecting heart rate variability was used to index changes in cardiac vagal tone. Pharmacological blockade studies have shown that RMSSD correlates well with frequency domain measures of high-frequency heart rate variability and is influenced by cardiac vagal tone (Cacioppo et al., 1994). A time series of interbeat intervals (IBI) was derived from the R–peak time series (sample rate 1,000 Hz) for every heartbeat. Data were controlled for artifacts, such as premature heartbeats, followed by a correction when necessary. RMSSD was calculated for every heartbeat from the five preceding and five following interbeat intervals.

Instruments

The Impact of Event Scale (Horowitz, Wilner, & Alvarez, 1979) is a widely used 15-item self-report questionnaire evaluating experiences of avoidance and intrusion that attempts to reflect the intensity of posttraumatic stress reactions. Horowitz et al. reported split-half reliability for the total scale to be .86 and acceptable internal consistency of the subscales (alpha of .78 and .80, respectively). We used the authorized German version of the IES (Ferring & Fillipp, 1994) that shows similar statistical properties.

The German version of the PTSD module (Wittchen et al., 1997) of the Structured Clinical Interview for DSM-IV (First, Spitzer, Gibbon, & Williams, 1996) was used to assess diagnostic criteria for PTSD before including participants in the study. All interviews were conducted by a trained clinician (MS) with more than eight years of experience in diagnostic interviews. Diagnostic reliability was not assessed.

The Response to Script Driven Imagery Scale (RSDI) (Hopper, Frewen, Sack, Lanius, & van der Kolk, 2007) was developed for measuring state reexperiencing, avoidance, and dissociative symptoms evoked by script-driven trauma imagery. The predicted three-factor solution was strongly supported by confirmatory factor analyses. The response format is a seven-point Likert scale, from zero for *not at all* to six for *a great deal,* with only those anchors at the extremes. The German translation of the RSDI underwent a retranslation procedure for checking accuracy. In the current study, the RSDI was administered in questionnaire form, directly after exposure to the trauma script.

Procedure

All trauma scripts were prepared by the study's principal investigator (MS) and described participants' most disturbing traumatic events, sequentially unfolding the details in the present tense and first person. Scripts were then read to the patient to check for any inconsistencies with their memories and were recorded onto audiotape. Assessment of script-related changes in psychophysiological activity took place after electrode placement and a 5-minute adaptation period. A sequence of two scripts was played back via tape recorder, in a fixed order: (1) 2-minute neutral script of imagining washing dishes followed by a 1-minute break; (2) 2-minute trauma script followed by a 5-minute break. Levels of subjective units of disturbance (SUDs) on an 11-point (0 to 10) scale and the (RSDI) were assessed immediately after the trauma script. With the exception of the first pretreatment assessment and the posttreatment assessment session, EMDR treatment started after asking for subjective disturbance and administering the RSDI-questionnaire; psychophysiological data were recorded throughout the treatment session. Mean values of all psychophysiological data were calculated for the first 60 seconds of each script. Script-related changes in psychophysiological activity were calculated by subtracting 60-second mean values during the trauma script from the neutral script.

Data Analysis

Linear mixed model analysis (procedure MIXED in SPSS) was applied for statistical comparison of pre- and post changes in psychometric variables and psychophysiological reactivity. Due to the known skewed distribution of RMSSD values a log transformation was applied before statistical comparison. Psychophysiological changes during the course of EMDR sessions were explored by comparing beginning-session and end-of-session values derived from linear regression of during-session interbeat intervals and related RMSSD values. Paired samples *t* test (two-tailed) was used for statistical comparison. Overall significance level was set at .05. Due to the small sample size and explorative nature of the study, no statistical correction for multiple testing was applied. Data were analyzed using SPSS version 10.

Results

This study includes psychophysiological data from 10 subjects receiving a total of 24 treatment sessions. Descriptive data analysis revealed that a mean of 17 sets of stimulation with eye movements per session were applied, ranging from 8 to 28 sets per session. The duration of trauma exposure (Phase 4 according to the EMDR standard protocol) per EMDR session ranged from 12 to 43 minutes (mean 27.6 minutes). Trauma script reactivity was measured at two pretreatment assessment points, before each of the 24 treatment sessions, and at posttreatment. A total of 44 assessments of psychophysiological reactivity to individualized trauma scripts reactivity was carried out.

Relationships Between Questionnaire and Physiological Variables

An analysis of the 44 trauma scripts showed the following relationships. Levels of subjective disturbance during the trauma scripts had a significant positive correlation with the Impact of Event Scale ($r = 0.83$, $p < .001$). Although there was a significant positive correlation between PTSD symptom severity as measured by the Impact of Event Scale and HR reactivity during the trauma scripts ($r = 0.49$, $p = .001$), the IES scores were not significantly related to script-related reactions in parasympathetic tone (RMSSD). Levels of subjective disturbance during the trauma scripts had a significant positive correlation with HR reactivity ($r = 0.52$, $p < .001$) and a significant negative correlation with script-related reactions in parasympathetic tone (RMSSD) ($r = -0.32$, $p = .03$).

Pre- and Post-EMDR Treatment Questionnaire and Physiological Variables

There were no significant differences between the scores acquired at the two pretreatment assessment points (see Table 1). A comparison of the second pretreatment scores and the posttreatment scores showed a statistically significant decrease in trauma-related symptoms (IES) ($F[2, 9] = 25.8$, $p < .001$), a significant decrease in subjective disturbance (SUD) during trauma script ($F[2, 9] = 13.4$, $p = .002$), as well as a significant decrease in acute symptoms of reexperiencing ($F[2, 9] = 22.3$, $p < .001$), avoidance ($F[2, 9] = 8.6$, $p = .008$), and dissociation ($F[2, 9] = 5.9$, $p = .023$) provoked by trauma script (RSDI). Reassessment of diagnostic criteria with SCID-PTSD after EMDR treatment revealed that 8 of the 10 patients no longer fulfilled criteria for PTSD.

Comparison of pretreatment and posttreatment values of psychophysiological reactivity to the individualized audiotaped trauma script showed a statistically significant decrease in heart rate reactivity ($F[2, 9] = 7.4$, $p = .013$), dropping from 9.5 beats per minute (bpm) ($SD = 1.7$) at the first pretreatment assessment and 7.6 bpm ($SD = 2.2$) at the second pretreatment assessment to 1.9 bpm ($SD = .68$) at posttreatment. A nonsignificant decrease in reactivity of RMSSD indexing stress-related reactions of parasympathetic tone was noticed after treatment ($F[2, 9] = 4.1$, $p = .056$).

During-Session Changes of Psychophysiological Variables

Comparison of the beginning-of-session and end-of-session values revealed a significant decrease of HR ($t[23] = 4.0$, $p = .001$) and a significant increase of RMSSD ($t[23] = 2.7$, $p = .012$), indicating higher parasympathetic activity at the end of the session (see Table 2).

Correlations Between During-Session Changes in Psychophysiological Values and Treatment Outcome

An analysis was conducted to examine the relationship between changes in the physiological variables that occurred over the session (i.e., the difference between

TABLE 1. Questionnaire Measures and Psychophysiological Reactivity Before and After EMDR Treatment

	Pre-1		Pre-2		Post		Statistical Comparison	
	Mean	*SE*	Mean	*SE*	Mean	*SE*	Pre-1 vs. Pre-2	Pre-2 vs. Post
IES	61.2	3.4	55.4	6.0	17.4	6.6	*ns*	$p < .001$
SUD	6.6	.43	6.9	.44	2.7	.80	*ns*	$p = .001$
RSDI reexperiencing	19.6	1.9	20.0	1.5	5.8	2.0	*ns*	$p < .001$
RSDI avoidance	6.7	1.6	8.5	1.9	1.7	1.2	*ns*	$p = .003$
RSDI dissociation	8.1	2.4	6.4	1.5	2.2	.96	*ns*	$p = .007$
ΔHR	9.5	1.7	7.6	2.2	1.9	.68	*ns*	$p = .033$
Δ(ln)RMSSD	−.39	.96	−.27	1.7	−.09	.05	*ns*	*ns*

Note. IES = Impact of Event Scale; SUD = Subjective Units of Disturbance (during trauma script listening); RSDI = Responses to Script Driven Imagery Scale; ΔHR = difference of heart rate (trauma script—neutral); Δ(ln)RMSSD = difference of parasympathetic tone (trauma script—neutral). Statistical comparison = linear mixed model (two-tailed); repeated factor = time.

TABLE 2. During-Session Changes of Heart Rate and Parasympathetic Tone (RMSSD)

	Beginning of Session		End of Session		Statistical Comparison		
	Mean	*SD*	Mean	*SD*	*df*	*t*	Significance
Heart rate	81.1	11.2	75.1	6.4	23	4.0	$p = .001$
(ln)RMSSD	3.3	0.54	3.6	0.58	23	2.7	$p = .012$

Note. (ln)RMSSD = root mean square of successive differences of interbeat intervals (estimate for parasympathetic tone). Statistical comparison = paired *t* test (two-tailed).

scores at the start and end of the session) and treatment outcome as assessed by session-to-session changes in symptom questionnaires (SUD, IES) and between session-to-session changes in HR and RMSSD reactivity during the trauma script. There was a significant positive correlation between during-session changes on HR and difference between presession SUD and end-session SUD ($r = 0.451$, $p = .027$). Correlations between during-session changes in parasympathetic tone (RMSSD) and SUD were in the expected direction but did not reach statistical significance. No significant correlations were found between IES and during-session changes in psychophysiological variables (see Table 3). However, changes in IES and changes in SUD were significantly positive correlated ($r = 0.68$, $p < .001$).

Session-to-session changes of HR reactivity during the trauma script were significantly positively correlated with during-session HR changes and significantly negatively correlated with during-session changes in parasympathetic tone (RMSSD). Session-to-session changes in RMSSD reactivity during the trauma script were significantly correlated with during-session changes in RMSSD and significantly negatively correlated with during-session changes in HR (see Table 3).

TABLE 3. Correlation Between During-Session Changes of Heart Rate and Parasympathetic Tone (RMSSD) with Script-Related Reactivity and Subsequent Changes in Psychophysiological Reactivity and Symptom Measures

	During-Session Changes	
	Heart Rate	(ln)RMSSD
Change in Δ HR	0.481*	−0.573**
Change in Δ (ln)RMSSD	−0.555**	0.718***
Change in IES	−0.260	0.246
Change in SUD	0.451*	−0.372

Note. ΔHR = difference of heart rate (trauma script—neutral); Δ(ln)RMSSD = difference of parasympathetic tone (trauma script—neutral); IES = Impact of Event Scale; SUD = Subjective Units of Disturbance (during trauma script listening).

*$p < .05$. ** $p < .01$. ***$p < .001$.

Figure 1 and Figure 2 illustrate the distribution of data comparing during-session changes in autonomic tone with session-to-session changes in script-related reactivity. Together, these findings indicate a significant association between during-session changes of psychophysiological activity and subjective (Subjective Units of Disturbance) and objective (HR-reactivity) measures of treatment outcome.

Discussion

This study investigated whether psychophysiological changes during EMDR sessions were related to subjective and objective reduction of PTSD symptoms in 10 patients suffering from single-trauma PTSD. Treatment duration followed each patient's individual needs and ranged from 1 to 4 sessions, resulting in a total of 24 EMDR treatment sessions from which psychophysiological data were completely recorded.

Treatment with EMDR was followed by a significant reduction of subjective disturbance and trauma-related symptoms as well as by significantly reduced psychophysiological reactivity to an individualized trauma script. The finding of decreased reactivity in HR to a traumatic reminder after treatment with EMDR replicates and extends findings from previous studies (Carlson et al., 1998; Renfrey et al., 1994; Rogers et al., 1999; Sack et al., 2007) also showing reductions in stress-related psychophysiological reactivity after treatment with EMDR.

Psychophysiological monitoring during treatment sessions revealed a significant decrease of HR and a significant increase in parasympathetic tone, showing psychophysiological dearousal in the course of sessions. The main finding of this study is a significant correlation between treatment outcome and during-session psychophysiological dearousal. Greater reductions in during-session psychophysiological activity resulted

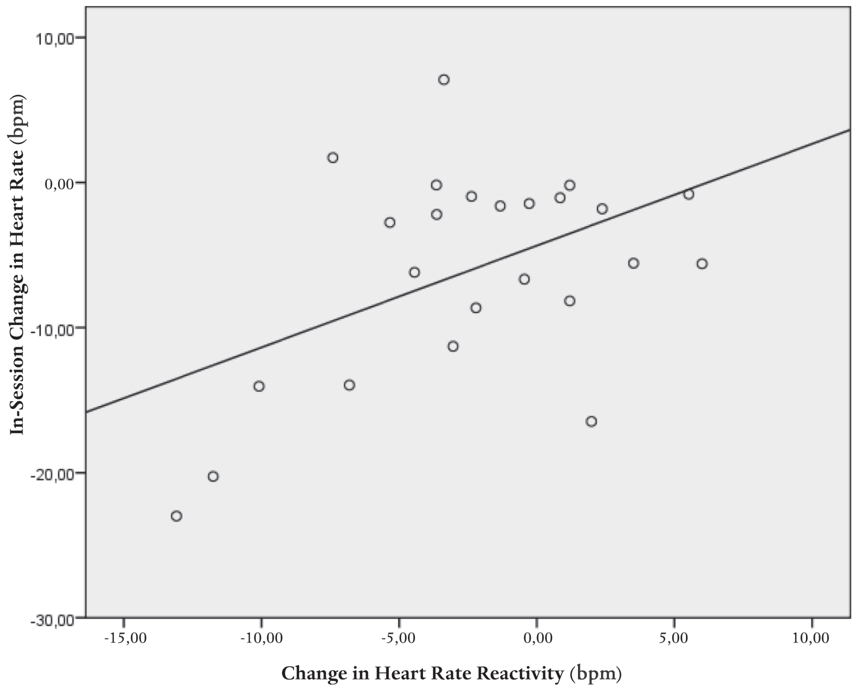

FIGURE 1. Scatter plot of during-session changes in heart rate and change in heart rate reactivity to trauma script.

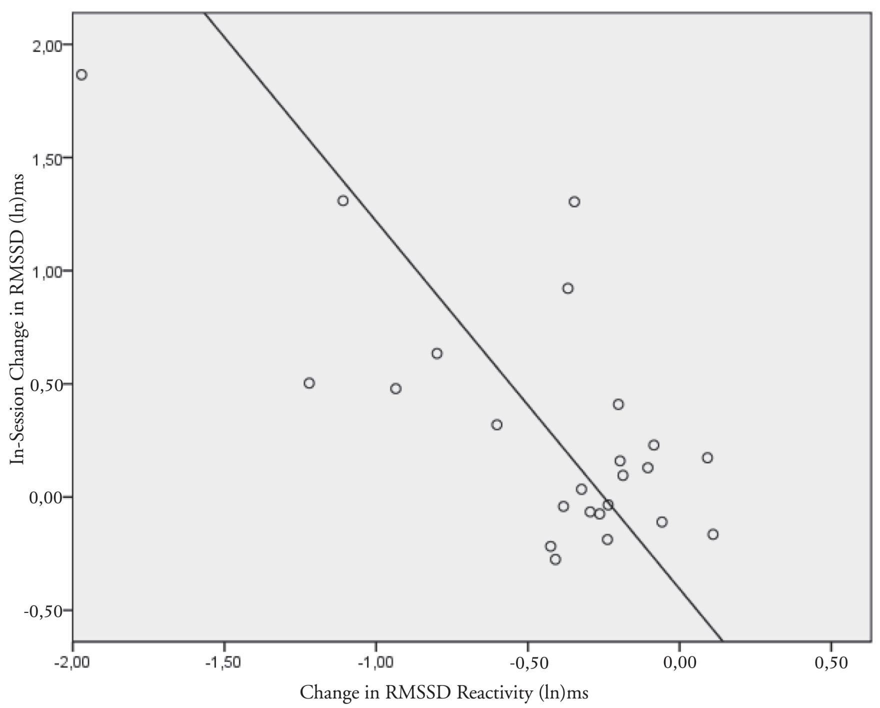

FIGURE 2. Scatter plot of during-session changes in parasympathetic tone and change in parasympathetic reactivity to trauma script.

Note. (ln)RMSSD = root mean square of successive differences of interbeat intervals (estimate for parasympathetic tone).

in significantly diminished HR reactivity during confrontation with an individualized trauma script as measured at the beginning of the next session. A significant positive correlation was found between during-session reductions in psychophysiological activity and during-session decrease of subjective disturbance (SUD). Correlations between changes in Impact of Event Scale and changes in during-session psychophysiological activity were found to be in the expected direction but did not reach statistical significance. These results demonstrate treatment outcome as measured by questionnaire assessment and by assessment of psychophysiological stress reactivity to be associated with during-session changes in psychophysiological activity. This opens the question of whether successful information processing during EMDR leads to during-session decreases in psychophysiological tone and decreases in symptom measures or whether decreases of psychophysiological tone are a prerequisite for successful processing of traumatic memories.

All patients terminated treatment, with no dropouts occurring after inclusion in the study. The symptoms of 8 of the 10 patients no longer fulfilled diagnostic criteria for PTSD at postassessment. The two women patients who continued to fulfill diagnostic criteria for PTSD after treatment suffered from accident-related posttraumatic symptoms. After inclusion in the study, one patient reported an ongoing conflict with her husband that was associated with significant disturbance and uncertainty about her current life situation. The other patient reported being very disappointed with a negative court decision for financial compensation due to accident-related injury, after inclusion in the study. From a clinical viewpoint, it is interesting that, for both patients, factors independent from trauma symptoms may have contributed to the relative non-response to treatment.

Limitations of this study are the sample size of only 10 patients treated with EMDR, which may have resulted in insufficient power to detect correlations with smaller effect sizes. The study would have benefited from the inclusion of a control group, because the observed reductions in psychophysiological reactivity could be theoretically caused by repetitive assessment with trauma script measurement. For ethical reasons, only active treatment with EMDR was chosen because the subjects' participation in the study was associated with the burden of repeated exposure to trauma script measurement. Although potentially indicative for emotional processing (Nishith, Griffin, & Weaver, 2002), heart rate response at the beginning of treatment sessions had not been calculated separately from trauma script reactivity. Other limitations of this study are that the two clinicians of the study were data collectors as well as researchers and that no independent check for adherence to the EMDR protocol was carried out.

The findings of our study support the habituation paradigm in the treatment of posttraumatic stress disorders, because during-session habituation of psychophysiological activation was found. However, habituation might be a consequence of successful processing of traumatic memory, and repetitive orienting responses or other biologically determined working mechanism may play a role in the efficacy of EMDR treatment (Elofsson et al., 2008; Sack et al., 2008). Our findings indicate that reduced psychophysiological activity at the end of treatment sessions was reflected not only by reduced heart rate but also by increased parasympathetic tone as measured by heart rate variability (HRV). Newer research findings indicate that HRV is associated with inhibitory influence and top-down control of emotional arousal and self-regulation (Hansen, Johnsen, Thornton, Waage, & Thayer, 2007).

We think that the habituation occurring in the EMDR treatment sessions is a consequence to successful processing of traumatic memory and that repetitive orienting responses together with other biologically determined working mechanisms may play a role in the efficacy of the treatment. Following the hypothesis of Stickgold (2002), bilateral stimulation may jump-start memory processing via an enhancement of parasympathetic tone employing the mechanism of orienting responses elucidated by following the waving hand with the eyes. This fits with the findings of Christman, Garvey, Propper, and Phaneuf (2003), who found that bilateral eye movements enhance the retrieval of episodic memories, and the observations of Parker, Relph, and Dagnall (2008), who showed that eye movements lead to the activation of memory networks. Although recent studies shed some light on possible working mechanisms of EMDR, we acknowledge that research on biological concomitants of implicit memory processing is still in its infancy. Studies investigating EMDR working mechanisms with up-to date research methods are urgently needed. Future research should investigate during-session psychophysiological changes in relation to central nervous system and cognitive processes. Monitoring of autonomic tone as well as of central equivalents of information processing may be promising for elucidating the mechanisms of the integration of traumatic memories in treatment methods such as EMDR.

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Acknowledgments. This study has been supported by a grant from EMDRIA-Europe and EMDRIA-Germany to Martin Sack.

Correspondence regarding this article should be directed to Dr. Martin Sack, Department of Psychosomatic Medicine and Psychotherapy, Klinikum rechts der Isar, Technical University Munich, Langerstr. 3, 81675 Munich, Germany. E-mail: m.sack@tum.de